NOVA SCHOOL OF SCIENCE & TECHNOLOGY

Eletrónica para Micro-Sistemas / Electronics for Micro-Systems

Individual Assignment Problems Solving Analysis

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Introduction

This is the problem series assignment which must be solved by each student individually. The resolution should be submitted on the moodle@FCT platform.

Problem 1

Consider the circuit, with one OPAMP, shown in Figure 1. This is an non inverting amplifier stage configuration. The objective of this exercise is to evaluate the impact of the OPAMP input offset voltage and OPAMP input bias current on the output.

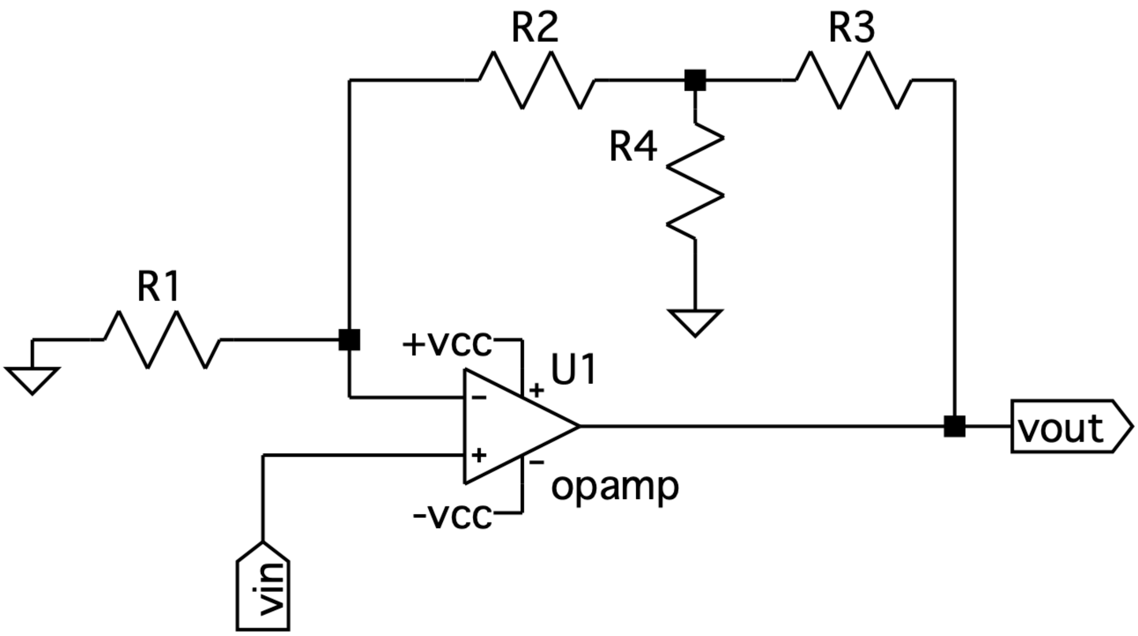

Figure 1 - Circuit schematic for problem 1.

- Considering an ideal OPAMP with a very high gain at low frequency, obtain the voltage gain vout/vin.
- Using the superposition theorem, obtain the expression of the output signal voltage resulting from the contribution of the input signal, offset voltage of the OPAMP (V_{off}), input current bias of the OPAMP inverting terminal (I_{bias-}) and input current bias of the OPAMP non-inverting terminal (I_{bias+}).
- Considering that the maximum output voltage swing of the OPAMP is [-VSAT,+VSAT] (for example -5 and +5V), obtain the corresponding maximum voltage input range that guarantees the linear operation of the circuit.
- Calculate the output noise at the output node.

Problem 2

Consider the active filter shown in Figure 2. This filter is composed of the cascade of one 1st order filter stage followed by one 2nd order Sallen-Key stage.

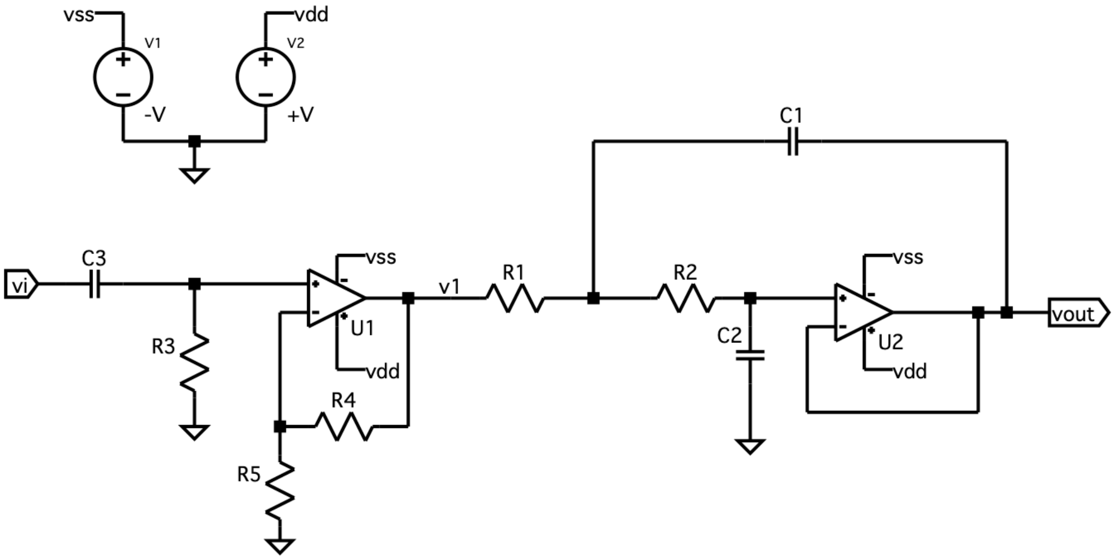

Figure 2 - Active filter.

R1=3.33kΩ, R2=62.9kΩ,

R3=120.8kΩ + NumAluno/(470000) kΩ,

R4=30kΩ + NumAluno/(1600) kΩ

R5=18kΩ, C1=0.9nF, C2=0.9nF,

C3=40.7nF - NumAluno/(470000) nF

- Identify the type of filter.
- Characterize the filter bandwidth (cutoff frequencies) and obtain the maximum gain value, considering ideal OPAMPs. You can use, for example, a Python script (recommended; however, excel, octave script, or other, are also accepted).
- Simulate the circuit in LTspice and obtain:
    - the frequency response (including group-delay) results (AC analysis);
    - step-response, in time domain (transient analysis).
    - Comment the results.
- Study the impact of the input offset voltages of both OPAMPs. Obtain the expression of the output signal (in the passband region), including the effects of the input offset voltages of both OPAMPs.
- Consider non ideal OPAMP with a gain bandwidth product (GBW) of 10kHz. Indicate if this OPAMP is adequate for the filter. You can use LTspice simulations to explain your conclusions. In case it is not adequate, specify the minimum GBW needed for the OPAMP.
- The maximum signal excursion at the output of an OPAMP is limited. Considering that the OPAMP has a rail-to-rail capability at the output, determine the maximum input signal amplitude below which the output does not saturate.

- Select a commercial OPAMP that fits the filter specifications. Explain which OPAMP parameters/criteria were considered in your decision. For example: GBW?, supply voltage?, …, price?, etc.
- Considerer an input sinusoidal input with 10 mV of amplitude and with a frequency inside the pass band of the filter. Obtain the signal to noise ratio at the output node. Consult the input referred noise value of the opamp indicated in the moodle page.
- Modify the circuit of Figure 2 to operate with only one power supply, i.e., propose a single supply version.

Problem 3

Obtain a low pass transfer function of a FIR filter with a cutoff frequency equal to the **last 3 digits of your student number** (for example: student number = 61420 → cutoff frequency = 420 Hz). Consider a sampling frequency of 80kHz. Write a short python script using the **firwin** method to determine the transfer function coefficients. Scripts in other languages are also accepted.

- Obtain the frequency response plots (magnitude, phase), considering a sampling frequency of 20kHz. Confirm that the simulated cutoff frequency is close to the wanted one? Suggestion: write a short Python script using **freqz** method from "scipy.signal" library.

- The microcontroller code that implements this filter can be written from the difference equations associated with this transfer function. Obtain the difference equations for this filter.

Problem 4

Consider IIR filter with the following transfer function in Z domain:

$$H(z) = 0.8 * \frac{1 + 6 * z^{-1} + z^{-2}}{1 - 0.36953 * z^{-1} + 0.19582 * z^{-2}}$$

- Obtain the frequency response plots (magnitude, phase), considering a sampling frequency of 80kHz. What is the cutoff frequency? Write a short Python script using **freqz** method from "scipy.signal" library. Scripts in other languages are also accepted.

- The microcontroller code that implements this filter can be obtained from the difference equations associated with this transfer function. Obtain the difference equation for this filter.

Problem 5

The circuit shown in Figure 4 is a thermostat which includes a comparator. The objective is to turn on or off an air fan depending on the temperature.

The thermistor is a negative temperature coefficient (NTC) sensor, with a nominal resistance of 5kΩ at 25ºC. The model is B57861S0502F045 from EPCOS/TDK (datasheet available on moodle@FCT). **For the analysis and design use the thermistor B-model.**
https://pt.mouser.com/ProductDetail/EPCOS-TDK/B57861S0502F045?qs=E%2F3ZYvLbbh8thE9LjoK34A%3D%3D

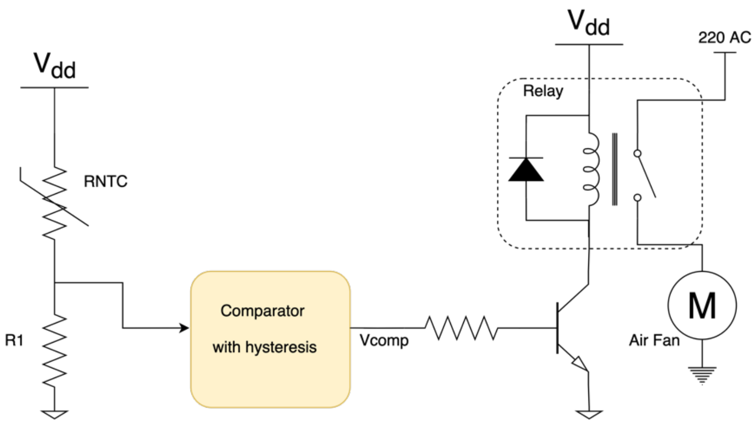

Figure 3 - Circuit schematic for problem 6.

Comparators are used to differentiate between 2 different input levels. However, a small noise variation on the input may cause the output level of the comparator to become unstable to briefly bounce and forth. Adding hysteresis is an effective way to solve this problem.

Design the NTC branch and an OPAMP based comparator with a hysteresis window shown in Figure 3.

Complete the design, by determining the resistance value of the resistor connected to the base of the NPN transistor. Consider that the transistor is the 2N2222 and the relay is the ST2-DC5V-F from Panasonic, whose datasheet can be found,
https://www.digikey.pt/en/products/detail/panasonic-electric-works/ST2-DC5V-F/2125706

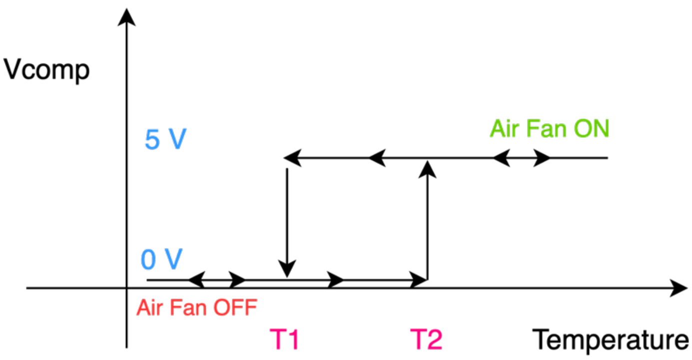

Figure 4 - Hysteresis window.

For the analysis and design consider:

- Temperature T1 equal to T1 = 40°C + (last digit of Student Number) °C
- Temperature T2 equal to T2 = T1 + 0.5°C
- MCP6004 OPAMP with a single supply, VCC = +5V. Consider the effect of the input offset voltage.
- NTC described previously.
- Transistor NPN: 2N2222
- Relay: ST2-DC5V-F from Panasonic

Suggestion: use your previous knowledge about comparator with hysteresis. A review can be found in this technical note from TI available or on moodle@FCT:

https://www.ti.com/lit/ug/tidu020a/tidu020a.pdf?ts=1638169469915.

Remark that the circuit analyzed on the technical note is an "inverting" comparator with hysteresis. However, the required design in this exercise corresponds to "a non-inverting" comparator with hysteresis, meaning that a circuit modification is needed to be implemented.

Analyze and evaluate the impact of the comparator input offset voltage in the transfer function

Design the same functionality using a microcontroller instead of an analog comparator. Present the block diagram of this solution as well as the code.

Problem 6

Consider a project where a pressure sensor measures liquid or air pressure and controls an electrical valve to regulate the pressure of the medium.

Based on the manufacturer's data, select a suitable pressure sensor and explain the operating principle of the sensor and the system. Begin by specifying the desired pressure range, then propose a system that uses the selected pressure sensor to control a valve (whether for air or liquid, depending on your chosen application). Assume the use of an ESP32 microcontroller in your design. Keep the description concise and clear, limited to 2-3 pages, including block diagrams and figures.

Suggested sensor family (other manufacturers may be considered):

https://automation.honeywell.com/us/en/products/sensing-solutions/sensors/pressure-sensors/26pc-series#resources